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Haptic memory and forgetting: a systematic review

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Abstract

Memory is a multiple system composed of encoding, storage and retrieval of information subsystems. The memory tactile, haptic memory submodality is connected to haptic perception; it concerns the active manipulation of objects. This study is a systematic review related to forgetting occurred in haptic memory. Articles was sought in electronic databases PsycINFO, PubMed, and Web of Science, using the keywords "haptic memory", "touch memory", "tactile memory", "tactual memory" separately, and then combined with the word "forgetting". These words were identified in 1655 publications. But lastly, six articles published between 2002 and 2012 were selected by a set of inclusion criteria. Largely referred to studies that used behavioral methods recognition procedures, and using real objects. However, the types of memory test used and the number of objects and the time interval between sessions of study and test had great variation.

Keywords: tactile memory; haptic memory; forgetting; systematic review.

Resumo

Memória háptica e esquecimento: uma revisão sistemática. A memória é um sistema múltiplo constituído por subsistemas de codificação, armazenamento e recuperação de informações. A memória tátil relaciona submodalidades da memória e percepção háptica e se trata da manipulação ativa dos objetos. Este estudo trata-se de uma revisão sistemática sobre o esquecimento ocorrido na memória háptica. Buscou-se nas bases de dados eletrônicas *PsycINFO*, *PubMed*, e *Web of Science*, utilizando as palavras-chave "*haptic memory*", "*touch memory*", "*tactile memory*", "*tactual memory*" de forma separada, e posteriormente combinadas com a palavra "*forgetting*". Essas palavras foram identificadas em 1.655 publicações, das quais foram selecionados por um conjunto de critérios de inclusão, seis artigos publicados entre 2002 e 2012. Grande parte dos estudos remeteu-se a métodos comportamentais sobre o reconhecimento de objetos reais. Contudo, os tipos de teste de memória utilizados, bem como o número de objetos e o intervalo de tempo entre as sessões de teste tiveram grande variação.

Palavras-chave: memória tátil; memória háptica; esquecimento; revisão sistemática.

Memory is considered a multiple system composed by encoding arrangements or subsystems, storage and information recovery (Baddeley, Anderson, & Eysenck, 2011; Tulving, 1972). It can be classified in different ways, varying on the type of encoded stimuli (visual, auditory, tactile, gustative, or olfactory), on how long the information is stored before recovered (short or long-term memory), and on its learning type **(**implicit or explicit memory). Explicit memory can be subdivided into two other categories referring to the content stored (semantic and episodic memory) (Tulving, 1972).

Although these categories correspond to different functions, they interact according to the sensory modality used in the stimuli encoding, which, on its turn, determines how the information is stored (Baddeley et al., 2011; Rodríguez & Orduña, 2007). According to Millar (1999) the conditions in which the information is received, such as type and quantity of available stimuli in the environment, as well as the superposition and convergence of these stimuli, have influence on the processing parsimonious organization, and on the information recovering.

The sensory modalities traditionally found in studies about memory are the visual and auditory ones, nonetheless, the scientific community has been directed towards the evaluation of memory through the haptic system (a modality of tactile sensory system) (Ballesteros, 1993; Ballesteros, Manga, & Reales, 1997;

Klatzky, Lederman, & Metzger, 1985; Pensky, Johnson, Haag & Homa, 2008; Standltlander, Murdoch, & Heiser, 1998). Gibson (1962), one of the first authors to introduce the study of the haptic system defines haptic perception as the sensation from an active touch of the hand on external stimuli.

According to Klatzky et al. (1985), the haptic system is highly accurate and fast to indentify a great amount of objects, retaining up to 100 objects, without losing information. Thus, it can be adequate for the memory assessment.

The haptic system was considered inadequate for indentifying objects for a long time, especially when compared to the visual system, for example, which acquires information through multiple parallel channels, providing information about luminance, color, movement, and depth (Ballesteros, 2008; Ballesteros, Reales, & Manga, 1999; Klatzky et al., 1985). Therefore, it was neglected the fact that the tactile sensory system involves the acquisition of several different information through several characteristic of the objects as weight, texture, temperature, pressure, and the like (Martinovic, Lawson, & Craddock, 2012). Thus, it is noticed that haptic perception is an independent system from visual perception, as well as it is neither secondary nor inferior to it (Ballesteros, 2008). According to Révész (1950), the haptic system demonstrates some independence from the visual system, being guided by its own principles.

Nonetheless, neuroimaging evidence indicate that visual cortical areas recruited for objects recognition are involved in haptic recognition, but not in auditory stimuli recognition (Grill-Spector, Kourtzi, & Kanwisher, 2001). These findings suggest it is possible to form a mental image of the object being haptically explored without looking at it due to modalities convergence (Amedi, Malach, Hendler, Peled & Zohary, 2001). Studies that investigated the areas involved in visual and haptic modalities indicate that the corresponding regions to dorsal and ventral visual pathways, activated in certain visual tasks processing, are also involved when the same tasks are performed by haptic stimulation (Amedi, Jacobson, Hendler, Malach, & Zohary, 2002; Amedi et al., 2001; James et al., 2002; Malach et al., 1995). The congruence with visual cortical areas contributes to a smaller loss of information as time passes by, indicating haptic memory to be a good estimate when it is intended to preserve information for a long period of time (Martinovic et al., 2012).

For considering that haptic system can be a good indicator of the memorization process and that few studies correlate this modality to the forgetfulness related to episodic memory, this study performed a systematic review of scientific articles, publications exclusively from the past 10 years (2002-2012) that used haptic memory as an evaluation method of episodic memory forgetting.

Method

The systematic literature search was accomplished on the second week of August 2012, on PsycINFO, PubMed, and Web of Science electronic database. Articles on the evaluation of forgetfulness related to haptic memory were prioritized. The keywords used were "haptic memory", "touch memory", "tactile memory", "tactual memory", used separately at first, and later combined with "forgetting". The references of the studies found were also reviewed in order to identify additional studies.

The inclusion criteria for the searched articles were:

1) to refer to explicit episodic memory;

2) Haptic condition to be one of the evaluated perceptive modalities;

3) to make use of free or cued recall, and/or recognition procedures;

4) to have as participants only healthy adults and/or elderly (older than 60 years of age), either man or women;

5) to use behavioral, psychophysical, neurophysiological, and neuroimaging tests;

6) to have title and abstract written in English (it was taken for granted that articles written in other languages, including Portuguese, have title and abstract in English);

7) to have been published between the years 2002 and 2012.

Results

In the initial search done by only one reviser using the chosen keywords resulted in 1,655 citations. After removing 198 repeated publications there were 1,457 articles left. Subsequently, two evaluators analyzed those articles by its titles based on the aforementioned inclusion criteria, which excluded 1,406 papers, resulting 51 articles. Later on, two new evaluators read the abstracts, selecting only six studies. The later 45 studies were excluded for not reaching the criteria. These data are better demonstrated in Figure 1.

The data collection from the six final articles was performed by four reviewers. The information collected were: authors and publication year; quantity of participants; type of memory evaluated; method; instruments and equipments; stimuli types; memory procedures; number of objects; time intervals between tests; and the results.

Only one study versed about haptic memory separately, not considering, therefore, other sensory modality for comparison. Five studies used behavioral methods only with recognition procedures, using real objects (spoon, comb, stapler, ball, etc.).

Nevertheless, the instruments and equipments used, as well as the number of objects, and the time interval between sessions varied greatly. Considering instruments and equipments the studies used tactile street maps**,** computer, earphone, blindfold, dynamic visual interference display**,** cardboard, rotating turntable, sensacube, and haptic tachistocospe. Likewise, the number of objects varied from 6 to 256. The interval between the study session and the test varied from immediately after to a week later. The results obtained from the different studies were analyzed separately, and later grouped in each specific characteristic, observed further on Table 1.

Discussion

The study on information acquisition through the haptic sensory system has gained great emphasis recently. Many researchers have tried to estimate the haptic modality contribution for information encoding and recollection (Ballesteros, 1993;

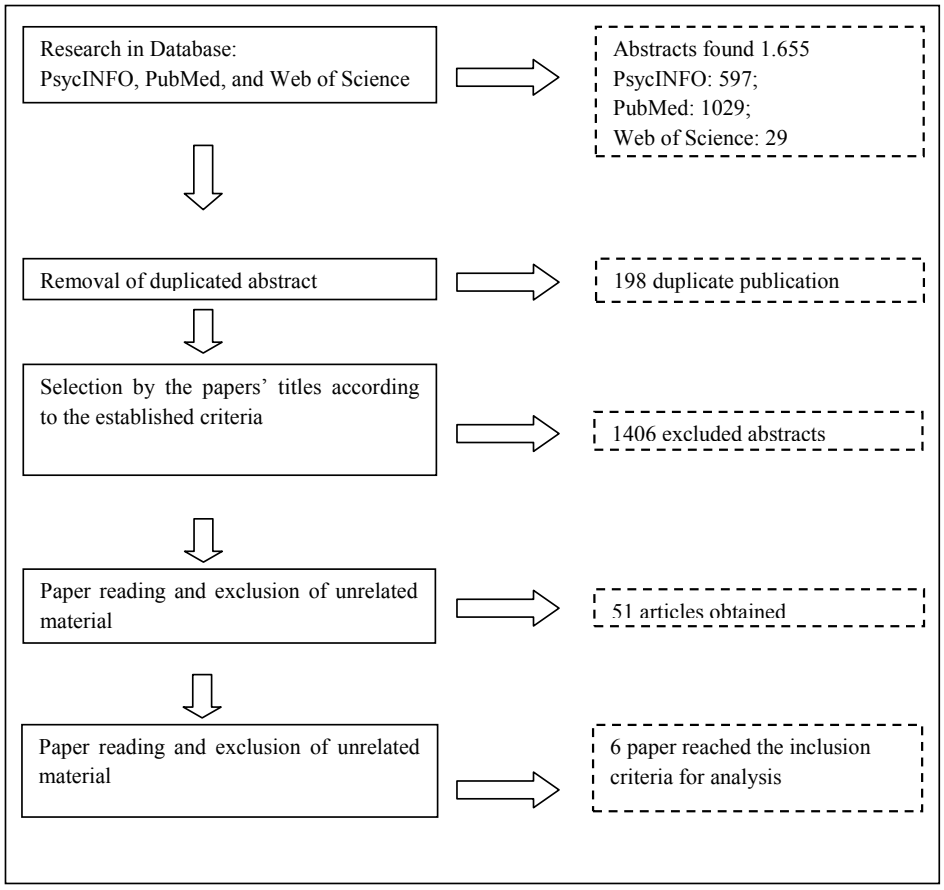

Figure 1
The article selections phase scheme.

Ballesteros et al., 1997; Klatzky et al., 1985; Pensky et al., 2008; Standltlander et al., 1998). In this sense, this review aimed at presenting an estimation of researches that evaluated haptic memory through different tests and time intervals.

Studies suggest that forgetfulness rates are influenced by the time elapsed between the acquisition and the tests runs, the type of tests (recollection or recognition), and by sensory levels of information acquisition (Christensen, Kopelman, Stanhope, Lorentz, & Owen, 1998; Davis et al., 2003). However, it is not clear the exact contribution of each one of these aspects in the mnemonic processes.

Millar and Al-Attar (2005) studied the influence of diffuse vision, complete vision, and peripheric vision in haptic memory of young adults ($M = 21.32$ years of age) by performing a memory localization test in spatial maps with high-relief pathways. It was verified that haptic memory improved considerably when aided by the complete and peripheric vision. These results corroborate electrophysiological and neuroimaging studies that found recruitment of primary visual cortex and medial occipital cortex in the recollection of tactile stimuli (James et al., 2002; Sathian, Zangaladze, Hoffman, & Grafton, 1997; Zangaladze, Epstein, Grafton, & Sathian, 1999).

In Nabeta and Kawahara`s (2006) study, long term memory was assessed in cross-modal recollection tests in young adults aging between 18 and 28 years. In cross-modal studies, studies, the study and the test phases are performed with different sensory modalities. When the test was visually accomplished low rates of objects recognition were found, despite a vantage over the haptic modality.

The precision in the cross-modal visual recognition indicated a high capacity of the haptic system in identifying objects in the study phase (93%), as previously stated by Klatzky et al. (1985); and Norman, Norman, Clayton, Lianekhamm and Zielke (2004). However, other authors have affirmed that haptic encoding process is very slow in comparison to the visual one (Martinovic et al., 2012).

Lacey and Campbell (2006) evaluated 80 young adults in recognition tasks associated to interference during encoding and recovering. The unimodal conditions used were auditory, visual, and haptic using familiar and unfamiliar objects; the last two conditions were also performed in the cross-modal way. The results demonstrate that verbal strategies used during interference facilitated encoding unfamiliar objects in all the modalities. In addition, haptic condition presented a better performance in encoding familiar objects. Besides, visual recognition was better for unfamiliar objects when compared to other modalities. These findings corroborate the evidences that unimodal visual performance is faster and more precise than unimodal haptic performance (Bushnell & Baxt, 1999; Easton, Srinivasn, & Greene, 1997).

In an attempt to clear up these conflicting information on the haptic memory nature, Pensky et al. (2008) developed a cross-

Table 1
Characteristic and Main Results of the Studies Included in the Review.

References	Participants	Type of memory	Method	Instruments/ equipments	Stimuli	Type of Recall	Number of objects	Time interval	Results
Millar and Al-Attar (2005)	50 young adults	Visual and Haptic Spatial Localization	B	Maps with Tactile High-relief street pathways	*	Recognition	6	Immediate	Complete, peripheric and in tunnel vision aided haptic memorization,
Nabeta and Kawahara (2006)	32 young adults	Haptic and Visual	B	Computer, earphone and table with curtain	Real objects	Recognition	256	20 min	The modality congruence in the presentation of tactile and visual objects reduced false recognition.
Lacey and Campbell (2006)	80 young adults	Haptic and Visual	B	Blindfold, Dynamic Visual Interference Display	Familiar and Unfamiliar Real objects	Recognition Interference	72	4 s (haptic stimuli) and 2 s (visual stimuli)	Haptic response interfere in the visual response to unfamiliar objects.
Pensky et al. (2008)	80 young adults	Haptic and Visual	B	Carton box, Rotating platform	Real objects	Recognition	80	Immediate and one week later	The level of visual information recognition surpassed the haptic and cross-modal modalities after one week.
Schifferstein, et al. (2010)	80 young adults	Visual localization, Auditory, Tactil, and Olfactory.	B	Sensacube (sensory cube)	3 D Abstract Objects	Recognition	10	*	Visual modality surpassed the others. Olfactory is equal to auditory and tactile.
Sebastián et al. (2011)	28 (14 young adults and 14 elderly)	Haptic	E	Haptic Tachistoscope	Familiar Real objects	Recognition	40	5 min	Young and older adults recruit different neural sources to perform recognition tasks.

* Information not available in the study; B = Behavioral; E = Electrophysiological

modal study by the combination of visual-visual, haptic-haptic, visual-haptic, and haptic-visual conditions for recognition tests (immediately after, and one week later) in young adults. This study demonstrated that even though recognition was more significant for the visual-visual condition than for the other three, in a long term, haptic information remained for an interval of at least one week.

In the study of Standltlander et al. (1998) in which haptic and visual memory were evaluated in adults and elderly with immediate free recall tests, both adults and elderly had a better performance in haptic than in the visual condition, suggesting that haptic condition ease future recollection for these populations. However, in the current study, contrary to Pensky et al. (2008), it was found a higher recollection rate for the elderly than for young adults with haptic stimuli.

In Pensky et al. (2008) and Standltlander et al. (1998) there were used tests with different recall, which impairs a direct comparison of the results; therefore, it is recommended the development of future studies to clarify the questions dealing with haptic forgetfulness using different age groups. Such comparisons could enlighten whether the tendency that accompanies the age increase is related to a more effective visual or haptic perception for a future information recall.

The comparison of sensory modalities has been frequently used with the purpose to demonstrate how much each sensorial system may influence the information recovery in memory tests. Schifferstein, Smeets, Streefkerk and Postma (2010) compared four sensory modalities for the localization memory in people aging from 17 to 35 years. Before the task accomplishment a recognition test was performed. The results presented a superposition of the visual system in comparison to the other three modalities, considering that olfactory and tactile systems had similar performance, and the auditory one had the lowest performance.

These results should be reconsidered when the forgetfulness rates are assessed, since the authors aimed at verifying how information is recovered at given time interval. In addition, in these studies real objects were not used, which increases the task complexity, making recognition difficult. Thus, new studies are necessary in order to corroborate to these results.

Sebastián, Reales and Ballesteros (2011) assessed haptic memory through recognition tests for a 5-minute interval. Took part in the study young adults ($M = 32.39$) and elderly ($M = 65.14$) with similar education levels, with no cognitive impairment. One haptic tachistocospe was used for the recognition of 40 real objects. The results of these studies show that even though young and elderly recruit different neural sources to perform haptic recognition, no statistically significant difference between the groups was found. These results are not sufficient to reach plausible conclusions since only one time interval was used. For that matter, new studies are necessary to assess forgetfulness through several intervals between the study phase and the test.

In general, the studies found and analyzed in this review were very heterogeneous considering the memory aspects evaluated, the methodological aspects suggested, and in the results found. Initially, it is emphasized the fact that no studies were found using free recall tests, which demand higher levels of controlled processing than recognition tasks (Tulving, 1985). Free recall involves an active process of searching and generating information, by means of recollection indication and decision-making processes, which depend on a controlled processing (Baddeley, 1982; Jacoby, 1991; Jones, 1987). Nonetheless, recognition supposes a decision process over the previous occurrence of a fact. This process is performed by two procedures: a) familiarity evaluation, which doesn't require a conscious processing, therefore being an automatic process; and b) identification after recovery, which demands a conscious and controlled elaboration process (Anderson & Bower, 1974; Mandler, 1980; Tulving, 1985). Secondly, on its majority, the studies used samples composed only by young adults. Thirdly, they didn't show convergence in relation to time interval used in memory evaluation.

In addition to those previously mentioned divergences, there were some gaps found in the searched studies. Therefore, the specifications regarding the sample selection criteria were not described, diminishing the results' generalization strength and possibly attributing the effects found to the great variety between the groups. Only one study was concerned in controlling some variables as level of education, depression and other cognitive impairments (Sebastian et al., 2011).

Therefore, taking into consideration these factors and the existence of a literature restrict to the haptic processing effects on the working memory (Braver et al., 1997; Millar, 1999), and in the implicit memory (Ballesteros, 2008), the haptic memory study needs more investigation about episodic forgetting.

The diversity of methods, procedures, and results found, announce the need for more studies that focus on the haptic memory. Consequently, it is suggested the creation of new designs involving other participants from different age groups, including the elderly, and other experimental protocols, by increasing several time intervals that permit precisely detecting the amount of information lost in each of these intervals. For that matter, the control of issues that can directly or indirectly interfere on these researches is necessary.

Final considerations

This review demonstrated that the variations of different methodological conditions, as well as the criteria for the sample and variables control used in haptic memory research, need to be reviewed and standardized. The type of test and time interval between the study phase and the test, education levels, depression and other cognitive impairments of participants may have direct influence on similar studies.

As it is considered a recent study field, the amount of information on haptic system is minimal. This lack of information is currently the base which marks the need for haptic memory to be studied more profoundly. These new studies become more imperative in the sense that the greater amount of memory deficits are found in the elderly, the neglected population in a large part of the studies searched in this review.

In this research, few studies were found that had elderly as participants. It indicates the need for more research in this direction to obtain a better understanding of the mechanism involved in memory processing in older people. Moreover, the study of different age groups may aid finding out the other sensory modalities that contribute to and the ones that don't contribute to haptic perception, and in clarifying the existence of modification on it along the human development. Therefore, it is suggested that future research investigate, specially, the effects of age on haptic memorization.

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